COMSOL Multiphysics® Model of Canine Elbow for Use in Investigating Medial Coronoid Disease

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Abstract

Introduction: The elbow joint in dogs constitutes a complex interaction of three bones, the humerus, radius and ulna. The primary articulation involves flexion of the forearm where the elbow acts as a hinge joint, with the humeral condyle seated in an arc formed by the ulnar trochlear notch and the radial head. A secondary articulation comes from rotation of the forearm when it acts as a pivot. This pivot articulation (radioulnar joint) arises from radial rotation while in contact with the ulna. Figure 1 displays the meshed geometry in COMSOL Multiphysics®.

Medial coronoid disease (MCD) is a common cause of lameness in dogs i.e. fracturing of the most prominent portion of the ulnar joint surface driven in flexion and in pivot against both the humerus and the radius [1]. The cause of MCD remains unknown, but prior studies suggest joint incongruency as an important factor in disease development [2]. Multiple hypotheses describe geometric abnormalities of the radius, ulna, and humerus. A shortened radius relative to the ulna may produce focal pressure on the medial coronoid process, akin to an 'avalanche' [2]. A second hypothesis is poor fit between the ulnar trochlear notch and humerus and a third is poor fit between the radius and ulna analogous to 'imperfect cogs' in a gear. The goal of this study was to develop a novel model using CT data to create a functional geometrically valid model in COMSOL to test these hypotheses and derive possible treatment strategies.

Use of COMSOL Multiphysics: Converting CT data to an appropriate COMSOL model required three steps outside of COMSOL. CT data was imported into Simpleware (Exeter, UK) and segmented to create the geometry of each bone. Second, the model was imported into Geomagic (Morrisville, NC) to smooth edges and simplify the geometry. The last step used Solidworks® (Waltham, MA) to further repair edges, create appropriate boundaries, and import into COMSOL through LiveLink™ for SolidWorks®. Once in COMSOL, stationary solid mechanics physics was applied and contact surfaces were defined. Appropriate boundary conditions were applied and the rigid connector feature was implemented in order to displace and rotate the radius. Meshing resulted in 599,835 degrees of freedom. Isotropic linearly elastic material properties of 12.55 GPa were used [3]. We were particularly interested in the stress patterns on the medial coronoid process of the ulna to better predict where fractures could occur in vivo.

Results: The study is ongoing, but preliminary results indicate high stress concentrations in the area where MCD occurs clinically. Figure 2 shows Von Mises stress on the ulna as a result of 16 degrees of radial rotation relative to the ulna. Figure 3 is an arthroscopic image of an MCD fragmented elbow while figure 4 shows high Von Mises stress within the corresponding area.

Conclusion: A robust COMSOL model of the canine elbow was created from a CT scan. With this model, multiple geometric abnormalities will be tested in order to better understand MCD. This knowledge will be crucial in developing improved techniques to prevent disease and treat clinically affected patients.

Reference

[1] Fitzpatrick N., Smith T. J., Evans R. B., and Yeadon R., 2009, “Radiographic and arthroscopic findings in the elbow joints of 263 dogs with medial coronoid disease,” Vet Surg, 38(2), pp. 213–223.

[2] Fitzpatrick N., and Yeadon R., 2009, “Working algorithm for treatment decision making for developmental disease of the medial compartment of the elbow in dogs,” Vet Surg, 38(2), pp. 285–300.

[3] Carter D. R., Smith D. J., Spengler D. M., Daly C. H., and Frankel V. H., 1980, “Measurement and analysis of invivo bone strains on the canine radius and ulna,” Journal of Biomechanics, 13(1), pp. 27–38.

Figures used in the abstract

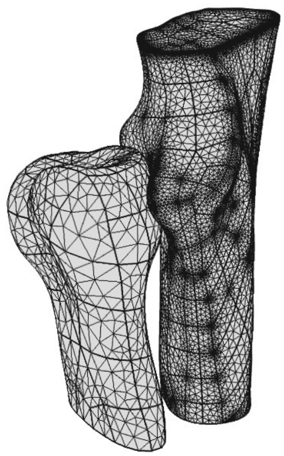

Figure 1: Radius left, ulna right

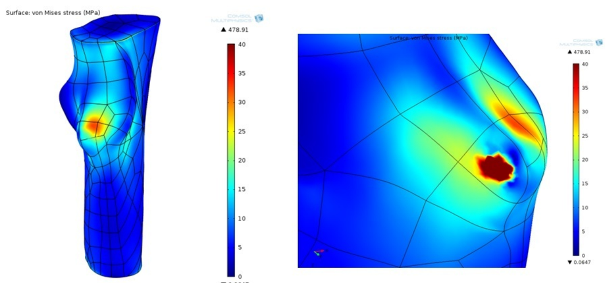

Figure 2: Von Mises Stress on Ulna

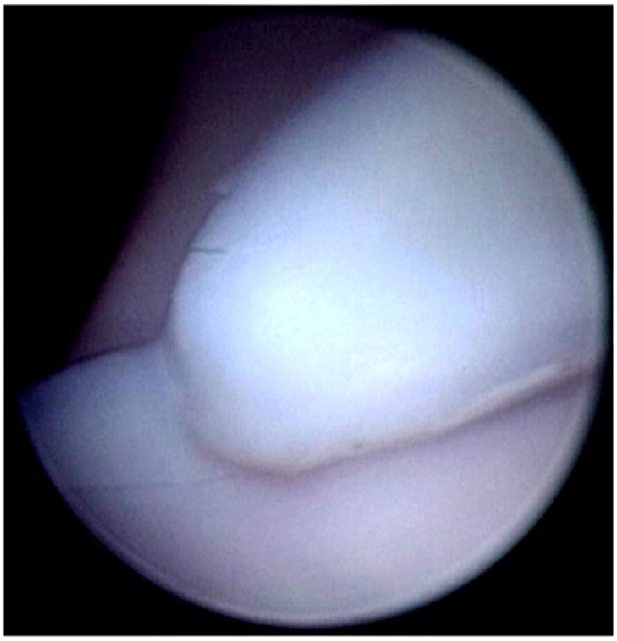

Figure 3: Arthroscopic image of fragment [2]

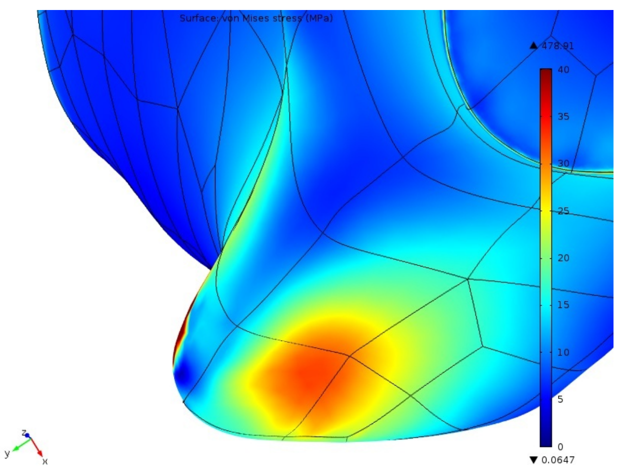

Figure 4: Stress at corresponding site on model